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A CRITIQUE OF HUGHES ASSOCIATES, INC. PAPER TITLED: "Analysis of the Performance of Ganged Operation of Smoke and Heat Vents with Sprinklers and Draft Curtains"

The following are comments on excerpts contained in a paper titled **"Analysis of the Performance of Ganged Operation of Smoke and Heat Vents with Sprinklers and Draft Curtains**" published by Hughes Associates, Inc. (HAI) and dated February 18, 2008.

> "*The gang operation concept involves opening all the vents within the coverage area of the sprinkler system in which the fire originates one minute after the first sprinkler has operated.*" **(Page 11)**

Schulte Comment: Dr. Beyler's assertion that venting does not have a significant adverse affect on the operation of standard spray sprinklers appears to be correct when automatic vents with an operating temperature equal to or greater than the operating temperature of the sprinklers are provided (**because the operation of the vents will be significantly delayed by the operation of the sprinklers and the number of vents which operate will be limited to a maximum of one vent, if any vents operate at all**).

Dr. Beyler's assertion regarding the impact of vents on the operation of standard spray sprinklers is obviously in error, however, when "ganged" operation of vents is provided and the operation of the vents occurs within one minute after the first sprinkler to operate. Sprinkler response times are known to vary with the location of the operating element of the sprinkler with respect to the ceiling, with the type of escutcheon used with the sprinklers (i.e. recessed escutcheons) and whether the escutcheon is in place (i.e. recessed escutcheons). **It should be obvious that an open vent located between a fire and sprinklers which have not yet activated will have a significant impact on the operating time of the sprinklers located downstream of an open vent.** The impact on the operating time of the sprinklers located downstream of an open vent will depend upon the orientation of the vent, as well as the size of the vent.

The large-scale tests sponsored by the National Fire Protection Research Foundation (NFPRF) in 1997/1998 clearly demonstrated that a 60 second delay in the opening of vents after the first sprinkler operates is not adequate to allow a sufficient number of sprinklers to operate prior to the "ganged" opening of the vents. The following table summarizes the number of sprinklers operating within the first 60 seconds of the operation of the first sprinkler and the number of sprinklers which operate after the first 60 seconds of the operation of the first sprinkler in the NFPRF large-scale test series:

	Number of A.S. Operating ≤ 60 Seconds After First Operating Sprinkler[1]	Number of A.S. Operating > 60 Seconds After First Operating Sprinkler
Test P-1	**2 A.S.**	**18 A.S.**
Test P-2	**7 A.S.**	**16+ A.S.**
Test P-3	**4 A.S.**	**15+ A.S.**
Test P-4	**3 A.S.**	**2 A.S.**
Test P-5	**2 A.S.**	**5 A.S.**

[1] Includes the first operating sprinkler.

Note: The comparison between Tests P-1 through P-5 and the HAI simulations is valid since the sprinklers with the same temperature rating and RTI have been utilized in both the NFPRF large-scale tests and the HAI simulations, as well as the same ceiling height and distance between the ceiling and the sprinklers.

Clearly, a significant number of sprinklers operate more than 60 seconds after the first sprinkler operates. **The assumption that all of the sprinklers which will have an effect of controlling and extinguishing the fire will operate within 60 seconds is erroneous. The assumption that the fewer sprinklers which operate is better than the operation of more sprinklers is also erroneous.**

Sprinklers which are not located over the fire, but which operate, perform a "pre-wetting" function. Wetted combustibles around the fire prevent the further horizontal extension of the fire. Confining fire spread to the initial combustibles involved in the fire by "pre-wetting" performs the control function performed by control mode (standard spray) sprinklers. Eventually, the sprinklers operating directly over the seat of the fire will extinguish the fire as the rate of heat released by the fire decays (due to the fact that the fire consumes the combustibles initially involved) and the sprinkler spray is able to reach the surface of the burning combustibles. (Per NFPA 13, extinguishment of the fire is expected within 30 minutes.)

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"*Comparison of sprinkler operations between vented and unvented cases clearly shows that the operation of sprinklers was not affected by smoke and heat vents or by smoke and heat vents with draft curtains. The time to first sprinkler operation, the number of sprinkler operations and the pattern of operation were not impacted by the venting system. The use of a one minute delay in vent operation allowed all sprinklers capable of applying water to the fire to operate before the vents operated, thus assuring that the sprinkler system performance would be unimpeded by the venting.*" **(Page 11)**

Schulte Comment: The data from the NFPRF large-scale tests (Tests P-1 through P-5) shows quite a variation in sprinkler operation times when compared with the modeling. The following is a summary of the response times for the first four sprinklers which operate from the NFPRF large-scale tests:

Test P-1: 76 sec, 134 sec, 171 sec, 303 sec **(227 second range)**
Test P-2: 100 sec, 108 sec, 115 sec, 121 sec **(21 second range)**
Test P-3: 67 sec, 72 sec, 105 sec, 123 sec **(56 second range)**
Test P-4: 93 sec, 94 sec, 140 sec, 199 sec **(106 second range)**
Test P-5: 74 sec, 75 sec, 146 sec, 147 sec **(73 second range)**

The range of operating times for the first four sprinkler which activate in all but one simulation run (Run #10) is between 69 seconds and 74 seconds (5 seconds).

The likely reason for the large variance in the range of operating times in Tests P-1 through P-5 is the wetting of non-operating sprinklers by water spray droplets carried upward in the fire plume.

The relatively small range of operating times for the first four sprinklers predicted by the model versus the far larger range of actual operating times for the first four sprinklers in full-scale tests clearly demonstrates that **the CFD model used by HAI is not capable of incorporating the interaction between water spray droplets and the fire plume.**

If the CFD model used by HAI is not capable of accurately predicting the operating times of the first four operating sprinklers, then the model's capability to accurately predict the operating times of other sprinklers is highly suspect.

If the CFD model used cannot accurately predict the interaction between sprinklers and water droplets, then the model certainly will not be capable of predicting the interaction between sprinklers, water droplets and vents which are opened at 60 seconds after the first sprinkler operates. **Hence, any conclusions drawn from the results of the simulations presented in the HAI paper are questionable at best.**

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"*For challenging fires without smoke and heat venting, loss of visibility was nearly complete. With smoke and heat venting, excellent visibility was maintained throughout the facility including in the area of actual sprinkler operation.*" **(Page 11)**

Schulte Comment: The statement above confirms that it is also HAI's opinion that automatic vents will not maintain visibility within a building if automatic vents do not operate in sprinklered buildings (as indicated is the case by Dr. Craig Beyler in his proposal to amend NFPA 204 (Proposal 204-26, Log #21) and in other Beyler documents and statements). In essence, this statement confirms statements contained in the fire investigation regarding visibility at the time of the arrival of the fire department at the fire in the bulk retail warehouse building in Tempe, Arizona on March 19, 1998.

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"*While only limited data for smoke production from controlled fires is available in the literature, the modeling results show that smoke and heat venting is very effective in removing smoke even for heat release rates associated with controlled fires. This facilitates fire department operations to extinguish the controlled fire.*" **(Page 12)**

Schulte Comment: The above statement does not address low heat release fires which only activate one or two sprinklers and which are controlled quickly. Vents operate most effectively when a hot layer of gases forms under the roof. Vents do not have the capability to vent smoke where the amount of heat produced by a fire is relatively small, such as where a single in-rack sprinkler controls a fire. Hence, it is possible that considerable smoke damage may occur in a building were the operation of the sprinkler system is highly effective in controlling the fire.

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"*This investigation has shown that ganged operation of smoke and heat vents is highly effective in removing heat and smoke from the building. The action of the smoke and heat vent system markedly improved the visibility throughout the building and significantly reduced the exposure of the building and contents to smoke. Draft curtains, although not vital to the performance of the smoke and heat vents, did limit lateral spread of smoke to other zones and enhanced the extraction of smoke from the building. The operation of the smoke and heat vent system had no effect on the operation of sprinklers and as such maintained the operational effectiveness of the sprinkler system while improving the conditions within the building in support of fire department operations.*"

Schulte Comment: The fact that "ganged" vent operation will reduce the quantity of smoke and heat in the building should be obvious. In fact, so obvious that there is really no need for an investigation of the concept of "ganged" roof vents in this regard. **What is not obvious however, is the issue of the impact of operating "ganged" roof vents on the ability of the sprinkler system to control the fire.**

Comparisons between the data collected in the NFPRF large-scale tests and predictions of the operating times of the first four sprinklers which activate by the CFD model clearly establish the fact that the model cannot accurately predict the operating time of sprinklers, other than the first sprinkler. Given this, the HAI investigation does not address the key issue of the impact of "gang" operation of roof vents on the operation of roof vents.

As previously indicated, there is no debate that an open vents will affect the operating time of sprinklers which have not activated where the open vent is located between the fire and sprinklers. The key issue is whether or not an open vent will have a significant adverse impact on the ability of standard spray sprinklers to control a fire where an open vent (or vents) located between a fire and sprinklers delays the operation of sprinklers on the downstream side of the vent.

In addition, it appears that the modeling does not address the issue of sprinkler "skipping" and sprinkler orifice obstructions. (The term "sprinkler skipping" is used to refer to a sprinkler or sprinklers in the vicinity of the fire fails to operate due to water spray droplets forming on the sprinkler activating mechanism. Sprinkler orifice obstructions occur mainly because gravel washes into the overhead portion of the sprinkler system due either to a lack of proper flushing of the underground supply piping or due to work on the municipal distribution system.)

It should also be noted that the HAI paper does not address the issue of "ganged" vent operation in dry pipe sprinkler systems and does not address the issue of the impact of higher and lower operating pressures, different sprinkler orifice sizes on sprinkler spray droplet size and the momentum of the droplets, as well as sprinklers with different operating temperatures and different RTIs.

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"*Smoke and heat vents, working in conjunction with draft curtains, have long been used as an effective fire protection measure. They can typically be found installed in industrial buildings, warehouses, stores, and malls. Their significance is recognized throughout the professional fire protection literature. The National Fire Protection Association (NFPA) has a standard dealing with smoke and heat vents [NFPA 204, 2007].*" **(Page 13)**

Schulte Comment: **This statement is essentially a re-write of the historical record of vents and draft curtains.** The issue of providing roof vents and draft curtains in buildings protected by standard spray sprinklers has been the subject of debate in the field of fire protection for more than 40 years.

One of the principal concerns over combining standard spray sprinkler protection and roof vents is that the opening of roof vents may have an adverse affect on the operation of sprinklers. Research conducted in the 1990's has determined that, while automatic roof vents will likely not have an adverse effect on the operation of the sprinklers, draft curtain installations are detrimental to the operation of sprinklers where a fire occurs in close proximity to a draft curtain.

It has been determined that draft curtains will have a detrimental affect the sprinklers which operate in a fire occurring near a draft curtain. It has also been determined that draft curtains may interfere with the operation of sprinklers which perform a "pre-wetting" function. This adverse effect was identified in research performed by Factory Mutual Research Corporation (FMRC) in 1994 and confirmed in research sponsored by the National Fire Protection Research Foundation (NFPRF) in 1997/1998.

In addition, the NFPRF research determined that (individually controlled) automatic roof vents will likely not operate in buildings protected by standard spray sprinklers where the mechanism which activates the vents has a temperature rating equal to or higher than the temperature rating of the sprinklers (assuming the sprinkler system is operational). Where roof vents do operate in buildings protected by standard spray sprinklers, the number of vents which operate will likely be limited to a maximum of one vent and the operation of the vent will likely be substantially delayed. Hence, the operation of automatic roof vents in sprinklered buildings is unlikely to interfere with the operation of the sprinkler system.

NFPA 204 states the following with regards to the installation of roof vents and draft curtains in buildings which are protected by sprinklers:

> "*Where provided, the design of venting for sprinklered buildings shall be based on a performance analysis acceptable to the authority having jurisdiction, demonstrating that the established objectives are met.*"
>
> "*While the use of automatic venting and draft curtains in sprinklered buildings is still under review, the designer is encouraged to use the available tools and data referenced in this document for solving problems peculiar to a particular type of hazard control [Miller 1980; Heskestad 1974; Waterman 1982; Troup 1994; Hinkley et al. 1992; Gustafsson 1992; McGrattan et al. 1998].*"
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> "*Chapters 4 through 10 represent the state of technology of vent and curtain board design in the absence of sprinklers. A broadly accepted equivalent design basis for using sprinklers, vents, and curtain boards together for hazard control (e.g., property protection, life safety, water usage, obscuration) is currently not available. Designers are strongly cautioned that use of venting with automatic sprinklers is an area of ongoing research to determine its benefit and effect in conjunction with automatic suppression.*"

Given the above information, the statement that the combination of roof vents and draft curtains are considered to be "*an effective fire protection measure*" is erroneous and appears to be intended to mislead readers who have little knowledge of the issues surrounding the use of roof vents and draft curtains in buildings which are protected by sprinklers.

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"*In this investigation, the effectiveness of smoke and heat venting with ganged operation of vents was evaluated using computational fluid dynamics (CFD). The modeled building was an 7,430 m^2 (80,000 sq. ft.) warehouse that was 8.23 m (27 feet) tall. The space was divided into two sprinkler systems each having a coverage area of 3,720 m^2 (40,000 ft^2). Thirty industry standard 2.44 m×1.22 m (8'×4') vents were placed in each coverage area in a manner such that they were not coincident with sprinklers and were not obstructed in any way.*" **(Page 13)**

Schulte Comment: The ratio of vent area to floor area utilized in the simulation is 1:41.67. This ratio is a relatively high ratio of vent area to floor area.

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> "*Ganged operation occurred over the entire sprinkler system coverage area for a single sprinkler system. It was initiated by the activation of the sprinkler system with a one minute delay from the detection of flowing water.*" **(Page 14)**

Schulte Comment: This statement is not consistent with the statement regarding the time of vent operation made on Page 11 of the HAI paper. The following is an excerpt from page 11:

> "*The gang operation concept involves opening all the vents within the coverage area of the sprinkler system in which the fire originates one minute after the first sprinkler has operated.*"

On page 11, it is indicated that the vents are opened *"one minute after the first sprinkler has operated*." On page 14, it is indicated that the vents are opened "*with a one minute delay from the detection of flowing water.*" Since water flow devices typically incorporate a delay to prevent false water flow alarms (due to surges in the municipal distribution system), one minute after the activation of the water flow device is not the same as "*one minute after the first sprinkler has operated*".

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"*FDS4 uses Lagrangian droplet transport to simulate the delivery of water from suppression systems. The droplets and the fluid mechanics are coupled. The flow of air and gas components affect the drag on the droplets. The force that the droplets exert on the surrounding gas shows up as a body force in the Eulerian momentum equations. This coupling allows the model to simulate sprinkler-smoke layer interaction.*"

Schulte Comment: The above statement appears to be intended to imply that the Fire Dynamics Simulator (FDS) model is capable of addressing the effect of water droplets entrained in the fire plume on sprinkler operation times. The comparison of actual sprinkler operation times obtained from the NFPRF large-scale tests (Tests P-1 through P-5) to the predicted operation times of the first four sprinklers from the FDS simulations clearly indicates that FDS model used in this research still cannot accurately predict sprinkler operation times. The inclusion of this statement in the report appears to be an attempt to "baffle" (and impress) those who not familiar with fire modeling. (The term "baffle" as used in the previous sentence is a term often used in the San Jose Fire Department (SJFD) Fire Prevention Bureau in the phrase "baffle them with bullshit". The "baffle them with bullshit" technique was often used by building designer in submittals to the SJFD. It appears that the HAI report is also employing this technique with the statement above and other statements included in the report.)

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Conclusions:

The report on the research conducted by HAI does not provide any new information with respect to the "ganged" operation of roof vents. It is intuitively obvious that the quantity of smoke and heat within a building will be less if 30 roof vents (providing a venting ratio of 1:41.67) are opened simultaneously 60 seconds after the first sprinkler operates.

The key issue with respect to the "ganged" operation of roof vents is whether the "ganged" operation of vents will have an adverse effect on the capability of a sprinkler system to control and extinguish a fire. It is obvious from a comparison of the operating times of sprinklers in the large-scale tests conducted in the NFPRF research in 1997/1998 to the operating times determined by the simulations that the FDS model is not capable of accurately predicting sprinkler operation times. Given this, the conclusions drawn in the report on the research regarding the impact of "ganged" vent operation on sprinkler operation and the capability of sprinklers to control and extinguish a fire are based upon data which is invalid. Hence, the conclusions drawn regarding the impact of "ganged" roof vent operation on the capability of sprinklers to perform their intended function cannot be supported by the simulations presented in this report.

Until sufficient information regarding the impact of “ganged” roof vent operation is provided by the proponents of this concept, it is Schulte & Associates’ recommendation that this concept not be utilized in building design.

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